Wood Ducks, *Aix sponsa* (Anseriformes: Anatidae), and Blackwater Impoundments in Southeastern North Carolina

Craig A. Harper[1],
James F. Parnell, and
Eric G. Bolen
Department of Biological Sciences, University of North Carolina at Wilmington, Wilmington, North Carolina 28403

ABSTRACT--Three small (<2.0 ha) newly constructed, wooded impoundments located on first-order blackwater streams were examined for suitability as habitat for wood ducks (*Aix sponsa*). We evaluated brood and roosting cover as well as availability of mast and invertebrate foods. Wood ducks used the new impoundments for nesting, brood rearing, feeding, and roosting. Feeding was heaviest on impoundments with dense cover where water oak (*Quercus nigra*) acorns were abundant. Brood rearing was restricted to sites with dense low cover. Roosting activity was highest where live, dense, woody cover was available. All sites were used by wood ducks throughout much of the year. Management recommendations include drawdown prescriptions designed to ensure live, woody shrub cover and continued mast production. We conclude that construction and active management of small blackwater impoundments offer a means of improving habitat for wood ducks and other wetland wildlife in the Coastal Plain of North Carolina.

Bottomland wetlands and other sites suitable for wood ducks have declined across North America (Dugger and Fredrickson 1992). North Carolina has been no exception, with alteration of more than 50% of the state's palustrine wetlands (Cashin et al. 1992). Thus, the creation of new wetlands is potentially significant in ameliorating the problem of wetland drainage, and is potentially significant to wood ducks. Three blackwater creeks at Camp Lejeune were impounded by the Environmental Management Division in October 1990, creating small (<2.0 ha) wetlands to be managed primarily for wood ducks. Although much is known about wood ducks elsewhere (Bellrose and Holm 1994), the usefulness of creating small impoundments as wood duck habitat is questionable.

---

[1] Present Address: Department of Forest Resources, Clemson University, Clemson, South Carolina 29634.

We monitored environmental parameters, changes in vegetation, and the response of wood ducks within these blackwater impoundments during the two years following construction and initial inundation.

STUDY SITES

The study was conducted on three small blackwater impoundments at Camp Lejeune Marine Base, Onslow County, North Carolina. The impoundments were located approximately 5 km east of Stone Bay (on the New River) and about 8 km northwest of the Atlantic Ocean.

Impoundment 1 (hereafter I-1) covered 1.2 ha with a mean depth of 1 m. Black gum (*Nyssa sylvatica*), red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), American holly (*Ilex opaca*), red bay (*Persia borbonia*), sweetbay (*Magnolia virginiana*), and willow (*Salix caroliniana*) formed a partial canopy over the inundation. Fetterbush (*Lyonia lucida*), wax myrtle (*Myrica cerifera*), and titi (*Cyrilla racemiflora*) furnished a thick undergrowth around and within I-1. Duckweeds (*Spirodela* spp., *Wolffia* spp., *Wolfiella* spp., and *Lemna* spp.) blanketed much of the water in spring and summer.

Impoundment 2 (I-2) covered 1.9 ha at a mean depth of 1.5 m. I-2 was heavily wooded by yellow poplar (*Liriodendron tulipifera*), sourwood (*Oxydendrum arboreum*), water oak (*Quercus nigra*), American holly, red bay, and sweetbay. Other woody vegetation included black gum, sweetgum, loblolly pine, fetterbush, wax myrtle, loblolly bay (*Gordonia lasianthus*), and white oak (*Quercus alba*). Duckweeds flourished during spring and summer.

Impoundment 3 (I-3) covered 0.36 ha with a mean depth of 1.5 m. Most of I-3 was open water, flanked by two wooded coves vegetated with water oak, loblolly pine, wax myrtle, American holly, sourwood, and red maple. Mats of bladderwort (*Utricularia biflora*) spread across the water, and organic matter supporting herbaceous plants such as yellow-eyed grasses (*Xyris* spp.) and club moss (*Lycopodium alopecuroides*) draped floating logs.

METHODS

Dissolved oxygen, pH, and Secchi disk readings were recorded monthly from June 1991 - December 1992 at each impoundment. Vegetation was sampled with a series of 15 m^2 circular plots, each selected randomly within a grid at a ratio of one plot per 0.40 ha. of pond surface. Plots were sampled in August 1991 and again in June and August 1992. All trees within each plot were counted and measured for diameter at breast height (dbh). The number of above-water stems of shrubs and vines was counted, and percent cover of herbaceous vegetation was visually estimated to the nearest 10% in a 0.50-m^2 quadrat.

Mast was sampled biweekly from September through December 1992 in square baskets of 1-m^2 surface area. Ten baskets were placed randomly at each wetland, with the restriction that they were spaced evenly around each wetland.

Five baskets were placed over water at no more than 50 cm of depth, and another five were placed in the adjacent uplands within 15 m of the apparent high-water mark. Mast captured in each basket was identified and weighed in the field to the nearest 0.01 g. The data obtained at each wetland were log 10 transformed because of heterogeneity of variances and were tested by species and location (inside or outside the impoundment) using a one-way ANOVA in the General Linear Models (SAS 1989) procedure. Transformed means were compared using the Student-Newman-Keuls test at the alpha = 0.05 level.

Macroinvertebrates were sampled in each vegetation plot monthly during April, May, June, and July 1992, using a plankton tow net and a sweep net. Three water surface samples were obtained with a plankton tow. The water column was sampled with a sweep net by making semicircular sweeps on the left, center, and right side of the plot. An attempt was made to sweep across the entire plot, thus sampling a standardized area. A sweep net also was used to sample the benthos by scraping the substrate with the net across the left, center, and right side of the plot. Samples were preserved in 45% isopropyl alcohol and identified using Thorp and Covich (1991). Specimens were air dried overnight, then ovendried at 55 C for eight hours, and their biomass was determined with a Mettler electronic balance. Data were log10 transformed because of heterogeneity of variances and tested for differences in total invertebrate biomass between wetlands with a one-way ANOVA in the General Linear Models (SAS 1989) procedure. Transformed means were contrasted using the Student-Newman-Keuls test at the alpha = 0.05 level.

Three cypress nest boxes designed for wood ducks were erected at each impoundment upon inundation in October 1990. Each nest box was erected on a steel post equipped with a predator-proof guard and supplied with wood shavings. Prior to the 1992 nesting season, sufficient numbers of nest boxes were added to provide one box per 100 m of shoreline at each of the three wetlands, thereby resulting in eight boxes at I-1, nine at I-2, and four at I-3. The boxes were inspected biweekly during May, June, and July and monthly August through April.

Flush counts were conducted biweekly on the impoundments between September and December 1992. All ducks flushed by an observer walking the perimeter of each wetland were recorded. Brood surveys were conducted each week during May, June, and July 1992 from blinds located at sites arbitrarily selected for their enhanced visibility of shrub-strewn habitat (Rumble and Flake 1982, Robb and Bookhout 1990). Broods were counted for two-hour periods beginning one-half hour before sunrise. Species, brood size, age-class (Gollop and Marshall 1954), and activities were recorded whenever broods were observed. Evening roost censuses were made biweekly between September and December 1992 from suitable vantage points adjacent to each wetland. Sampling effort and number of counts were identical at all impoundments. Flush and roost count data were analyzed by Chi-square tests to detect differences among wetlands.

RESULTS AND DISCUSSION

Dissolved oxygen was low at all three sites, averaging 2.0 - 2.1 ppm with a range of 0.4 - 6.6 ppm. Acidity was similar among impoundments, averaging 5.1 - 5.4 with a range from 4.1 - 6.1. Secchi disc readings also were similar with a range from 0.18 - 0.93 m.

Water control structures in I-1 and 1-3 remained closed throughout the two years of this study, while I-2 was partly drained half-way through the second year. Density of living upland vegetation within each impoundment diminished with time after flooding, whereas the density of aquatic plants increased (Table 1). Most woody vegetation at I-1 remained vigorous during the first year of inundation, but after two years more than 55% had died. Duckweeds and bladderwort first appeared during the summer of 1991 and covered approximately 50 % of the water's surface by the following summer. Aquatic emergent vegetation, including cattail (*Typha latifolia*), common rush (*Juncus effusus*), arrowhead (*Sagitarria latifolia*), and swamp loosestrife (*Decodon verticillatus*), was pioneering along the perimeter of I-1 by the second summer of inundation (Table 1). About 75% of woody vegetation at I-2 was dead by the end of the first growing season; 90% was dead a year later. Duckweeds and bladderwort quickly colonized I-2 and covered more than 40% of the surface one year after inundation (Table 1). Downed timber and dying, woody, emergent vegetation at I-2 provided conditions generally favored by wood ducks and their broods in the southern United States (see Cottrell et al. 1990). However, favorable conditions declined after two years of inundation, as woody cover died and disappeared rapidly creating a more open impoundment.

A lack of inundated woody vegetation at I-3 resulted in an open pond, except for one wooded cove and vegetation bordering the stream that fed the impoundment. Some perimeter vegetation was inundated when the water-control structure was closed. Plant mortality in I-3 thus occurred primarily in the wooded coves, which covered only 0.14 ha. Aquatic vegetation present at I-3 consisted primarily of bladderwort and duckweeds. Cattail was growing along the perimeter of I-3 by the end of the second growing season, and floating organic muck supported thick patches of swamp loosestrife. Swamp loosestrife, giant cane (*Arundinaria gigantea*), and fetterbush within and along the wooded coves offered cover for wood ducks as they foraged on water oak acorns.

Mast production varied greatly among impoundments. In the uplands adjacent to the impoundments, more mast was collected at I-1 (158.7 g, of which southern red oak acorns contributed 148.5 g) than I-2 (52.2 g) or I-3 (68.7 g). Mast collected in baskets within the impoundments probably better represents availability in terms of food for wood ducks. However, wood ducks were

Table 1. Changes in density[a] of live and dead vegetation in three blackwater impoundments at Camp Lejeune between August 1991 and August 1992.

Density (stems/m^2)

Wetland	Date	Woody Emeragent Vegetation			Aquatic Vegetation	
		Alive	Dead	% Dead	Alive[b]	% of Total
I-1(3 plots)[c]	August 1991	3.42	0.36	10	0	0
	June 1992	1.53	2.05	57	5.00	58
	August 1992	1.22	1.84	60	8.00	72
I-2(4 plots)	August 1991	0.88	2.78	76	.38	9
	June 1992	0.64	3.28	84	2.08	35
	August 1992	0.42	3.45	89	6.50	63
I-3(2 plots)	August 1991	3.77	0.00	0	.92	20
	June 1992	1.67	1.30	44	0.42	12
	August 1992	1.32	1.87	59	3.50	52

[a] Densities of aquatic plants (e.g., duckweed) derived from estimates in 0.5 m^2 plots.

[b] Aquatic plants include floating plants and herbaceous emergents.

[c] Each plot = 15 m^2.

observed feeding upon water oak acorns both at the water's edge and as far as 5 m above the shoreline of the wooded coves at I-3. Within the coves of I-3, water oaks yielded significantly ($p < 0.05$) more acorns (>28.0 g/m^2) than at I-1 or I-2 and attracted large numbers of wood ducks on a regular basis.

Acorn yields adjacent to the impoundments were similar to those in Missouri, where the upper range of acorn production in an upland forest varied from 4.0 to 25.5 g/m^2 during a 2-year period (Dalke 1953). Elsewhere in Missouri, pin oaks (*Quercus palustris*) within green-tree reservoirs produced an average of 14.2 g/m^2 (McQuilken and Musbach 1977).

Invertebrates are important waterfowl foods because of their protein and mineral contents, which are essential for egg production in hens and tissue growth of chicks (Krapu 1974, Swanson et al. 1974, Drobney and Fredrickson 1979, Drobney 1990). Invertebrate biomass within the impoundments ranged from 0.06 - 0.20 gm/m^2 (Table 2). Insects in the order Odonata (primarily Libellulidae) and Heteroptera (primarily Notonectidae) were the most abundant invertebrates. Most other groups were much less abundant (Table 2).

Table 2. Macroinvertebrate biomass[a] (in grams) in three blackwater impoundments at Camp Lejeune in April, May, June, and July 1992.

Taxa[b]	Pond		
	I-1	I-2	I-3
Chelicerata			
Araneae	0.01	0.05	0.01
Crustacea			
Amphipoda	0.02		
Decapoda		2.22	1.34
Insecta			
Coleoptera	0.27	0.33	0.07
Diptera	tr[c]	0.09	tr[c]
Heteroptera	4.91	1.34	0.36
Megaloptera	0.02	0.45	
Odonata	2.10	8.39	0.07
Total for all plots	7.33	12.87	1.85
Average/ plot	2.44	3.22	0.93
Number Plots (15m^2)	3	4	2

[a] Includes adults, nymphs, pupae, and larvae.
[b] For further taxonomic breakdown, see Harper (1993).
[c] tr = trace.

While investigating invertebrate productivity within a blackwater river in south Georgia, Benke et al. (1984) recorded 20-50 times more standing stock biomass on snags than in sandy habitat and 5-10 times more than in muddy habitat. They also found increased species richness on snag habitats as compared to other benthic habitats and concluded that production on snags appeared to be limited by available substrate. Thus, blackwater impoundments with significant amounts of flooded vegetation and downed timber (such as I-2 in our study) seem to provide habitat for a larger standing stock and increased production over riverine sites (e.g., non-impounded blackwater streams). High diversity and biomass of invertebrates make an important contribution to nesting and brooding wood ducks.

Wood ducks utilized the impoundments as nesting and brooding sites during both years of the study. One wood duck nest was located in 1991 (nine boxes were available). In 1992, two wood duck nests were among 15 bird nests found in 21 boxes available on the impoundments. Other birds using the nest boxes included eastern bluebirds (*Sialia sialis*), Carolina wrens (*Thryothorus ludovicianus*), great-crested flycatchers (*Myiarchus crinitus*), and prothonotary warblers (*Protonotaria citrea*).

Broods were sighted 34 times on I-1 during the survey period (May - June 1992). Because no eggs hatched in nest boxes at I-1, these broods either emigrated from other wetlands or hatched from nests in natural cavities nearby. The thick cover of fetterbush, titi, wax myrtle, honeysuckle (*Lonicera japonica*), and blackberry (*Rubus* spp.) around and within I-1, coupled with an abundance of invertebrates, made this impoundment an attractive brood rearing site. Molting adults also were observed within I-1 during brood surveys. Broods and adults were observed using floating logs in I-1 as loafing sites.

Brood habitat also was favorable at I-2, where broods were sighted on 35 occasions. The largest of these consisted of seven ducklings, but because this brood was observed before any clutches hatched in nest boxes located at I-2, the ducklings must have come from another site or a natural cavity in the local area. Movement of broods should not be unexpected in light of the mobility McGilvrey (1969) recorded for wood duck broods on impoundments elsewhere.

Thick cover at both I-1 and I-2 precluded precise censuses of broods; however, two broods were commonly observed concurrently on each impoundment, thus providing a conservative estimate of use. This compares favorably with the average of three broods per sampling date observed on impoundments of 0.71 to 2.70 ha in South Dakota, where visibility was much greater (see Rumble and Flake 1982). Similarly, Belanger and Couture (1988) recorded the greatest density of dabbling duck broods (2.0 broods/ha) on man-made ponds containing >30% cover and 0.35 g of invertebrate biomass per m^2, similar to conditions at I-1 and I-2.

Broods were not observed at I-3 during the survey, and the 10 ducklings that hatched from a nest box there in 1991 left the impoundment shortly afterward. The relative lack of invertebrates and plant cover, along with the small size of I-3, likely contributed to the absence of broods (Sousa and Farmer 1983, Drobney and Fredrickson 1979, Haramis 1990). Continued use of these impoundments as brood cover will depend on the schedule of flooding and drawdown. Brooding, molting, and roosting wood ducks depend on thick cover.

Unless managed to maintain living woody cover, impoundments will, in time, become more open, much like beaver (*Castor canadensis*) ponds.

Significantly ($p < 0.05$) fewer wood ducks were flushed from I-2 (n = 38) than I-1 (n = 82) and I-3(n=71). Numbers of wood ducks using the impoundments increased dramatically during autumn. Numbers recorded during flush counts were highest in November: I-1 (n = 50), I-2 (n = 20), and I-3 (n = 45). Decreased density of vegetation within I-2 probably accounted for fewer ducks flushed. Mortality of woody vegetation was highest at I-2 in 1992. By fall 1992, almost 90% of the standing vegetation within I-2 was dead, whereas only about 60% had died in I-1 and within the coves of I-3 (Table 1). Apparently, the availability of acorns in the two wooded coves at I-3 attracted wood ducks to these specific sites, which were the only locations on I-3 where wood ducks were flushed (i.e., no ducks were flushed from open water).

Wood ducks used I-1 and I-2 regularly for roosting during autumn and winter. Roosting activity increased from a low average of seven wood ducks per night on I-1 and 10 wood ducks per night on I-2 in September to a seasonal high of 140 per night on I-1 in November. Dense, low, evergreen shrub cover within I-1 similar to conditions described by Parr et al. (1979), provided attractive roosting habitat. Differences in cover apparently influenced the degree to which each site served as a roosting area, because significantly ($p < 0.05$) more wood ducks roosted under the live vegetation in I-1 as opposed to the dead vegetation in I-2. While only 10 wood ducks per day were flushed from I-2 in November, many more (average 65/night) sought roosting cover at night. Because very few acorns were available within I-1 or I-2, we believe wood ducks flushed during the day were loafing and not necessarily actively feeding. The wooded coves of I-3 were presumably too narrow for use as a secure roosting area. Wood ducks avoided roosting on I-3, which was mostly open water, thereby underscoring the value of impoundments with thick living emergent woody vegetation for loafing and for roosting.

MANAGEMENT CONSIDERATIONS AND CONCLUSIONS

The presence of myriad, first-order blackwater rivulets and streams in eastern North Carolina offers opportunities for creating many small impoundments suitable as habitat for wood ducks and many other species. Within a year of construction, small wooded impoundments were used readily by wood ducks for nesting, rearing broods, molting, roosting, and feeding. Depending upon physiographic features of each site (e.g., presence of live, low, woody cover; size of impoundment; topography; presence of preferred mast trees; etc.), use by wood ducks varied among the impoundments, yet certain biological needs were met at each.

Management goals for waterfowl on small impoundments are best achieved where water levels can be manipulated (Johnsgard 1956). Additionally, water-level management enhances biodiversity in wetland environments (Fredrickson and Taylor 1982). Maximum benefits are achieved when water-level management follows a schedule of drawdowns and flooding designed to maintain suitable communities of food and cover plants (Fredrickson and Taylor 1982, Fredrickson and Batema (no date), Fredrickson 1991). When managing small impoundments for wood ducks, we recommend initiating a flooding and drawdown schedule that allows maintenance of living, emergent woody vegetation at a density of > 3 - 5 stems/m^2 where possible. Drawdowns and flooding should be completed slowly (i.e., approximately 3 weeks), thereby maximizing food availability (e.g., invertebrates and mast) within the wood duck's foraging niche (<20 cm water depth) and allowing time for the establishment of moist-soil vegetation. Drawdowns should be timed so that they coincide with the spring migration of wood ducks. When managing for broods, drawdowns should not be completed until August, when most wood duck broods have fledged. Upon drawdown, areas inundated for brood utilization during the growing season should not be flooded again for 2 - 3 years to allow complete aeration of soil in order to perpetuate live woody cover. Reflooding in the fall should be timed so that at least 85% of the impoundment is inundated for the peak migration period of wood ducks (for our study, the first week of November. (See Harper 1993 for additional details.)

Water-level management enables managers to provide needed resources for wood ducks year-round. Obviously, this would be very difficult with only one wetland; however, with a complex of small, managed impoundments, the task is more feasible. With a schedule where an impoundment provides flooded cover only every 2 to 3 years, it is essential to have several impoundments that are diverse and can be inundated on a rotation, thus meeting the various needs of wood ducks each year. Three ponds, with one flooded each year and with the other two recovering, appear to represent a minimal management unit.

Although it is usually possible for landowners to construct small impoundments on small streams for wildlife enhancement, the regulatory office of the local United States Army Corps of Engineers should always be contacted prior to initiating work to determine the effect of regulations relative to section 404 of the Clean Water Act.

ACKNOWLEDGMENTS --We are indebted to Charles Peterson and his staff at Camp Lejeune for their financial and logistical support. The counsel of Martin Posey, Department of Biological Sciences at the University of North Carolina at Wilmington and Hoke Hill, Department of Experimental Statistics, Clemson University, was most helpful. The University of North Carolina at Wilmington provided basic support.

LITERATURE CITED

Belanger, L., and R. Couture. 1988. Use of man-made ponds by dabbling duck broods. The Journal of Wildlife Management 52:718-723.

Bellrose, F. C., and D. J. Holm. 1994. Ecology and management of the wood duck. Stackpole Books, Mechanicsburg, Pennsylvania.

Benke, A. C., T. C. Van Arsdall, Jr., D. M. Gillespie, and F. K. Parrish. 1984. Invertebrate productivity in a subtropical blackwater river: the importance of habitat and life history. Ecological Monographs 54:25-63.

Cashin, G. E., J. R. Dorney, and D. J. Richardson. 1992. Wetland alteration trends on the North Carolina coastal plain. Wetlands 12:63-71.

Cottrell, S. D., H. H. Prince, and P. I. Padding. 1990. Nest success, duckling survival, and brood habitat selection of wood ducks in a Tennessee riverine system. Pages 191-197 *in* Proceedings of the 1988 North American wood duck Symposium, (L. H. Fredrickson, G. V. Burger, S. D. Havera, D. A. Graber, R. E. Kirby, and T. S. Taylor, editors.). St. Louis, Missouri.

Dalke, P. D. 1953. Yields of seeds and mast in second growth hardwood forest, southcentral Missouri. The Journal of Wildlife Management 17:378-380.

Drobney, R. D. 1990. Nutritional ecology of breeding wood ducks; a symposium for wetland management. Pages 77-82 *in* Proceedings 1988 North American wood duck Symposium, (L. H. Fredrickson, G. V. Burger, S. P. Havera, D. A. Graber, R. E. Kirby, and T. S. Taylor, editors.). St. Louis, Missouri.

Drobney, R. D., and L. H. Fredrickson. 1979. Food selection by wood ducks in relation to breeding status. The Journal of Wildlife Management 43:109-120.

Dugger, K. M., and L. H. Fredrickson. 1992. Life history and habitat needs of the wood duck. Leaflet 13.1.6. Waterfowl management handbook. United States Fish and Wildlife Service, Washington, D.C.

Fredrickson, L. H. 1991. Strategies for water level manipulations in moist-soil systems. Leaflet 13.4.6. Waterfowl management handbook. United States Fish and Wildlife Service, Washington, D.C.

Fredrickson, L. H., and D. L. Batema. (No date). Greentree reservoir management. University of Missouri-Columbia, Puxico, Missouri.

Fredrickson, L. H., and T. S. Taylor. 1982. Management of seasonally flooded impoundments for wildlife. Resource Publication 148. United States Fish and Wildlife Service, Washington, D.C.

Gollop, J. G., and W. H. Marshall. 1954. A guide for aging duck broods in the field. Mississippi Flyway Council Technical Section (unpublished mimeo.).

Haramis, G. M. 1990. Breeding ecology of the wood duck: a review. Pages 45-60 *in* Proceedings of the 1988 North American wood duck Symposium, (L. H. Fredrickson, G. V. Burger, S. P. Havera, D. A. Graber, R. E. Kirby, and T. S. Taylor, editors.). St. Louis, Missouri

Haramis, G. M., and D. Q. Thompson. 1984. Density-production characteristics of box-nesting wood ducks in a northern greentree impoundment. The Journal of Wildlife Management 49:429-436.

Harper, C. A. 1993. Small wooded blackwater impoundments: their role as wood duck habitat. M.S. Thesis, University of North Carolina at Wilmington.

Johnsgard, P. A. 1956. Effects of water fluctuation and vegetation change on bird populations, particularly waterfowl. Ecology 37:689-701.

Krapu, G. L. 1974. Foods of breeding pintails in North Dakota. The Journal of Wildlife Management 38:408-417.

McGilvrey, F. B. 1969. Survival in wood duck broods. The Journal of Wildlife Management 33:73-76.

McQuilkin, R. A., and R. A. Musbach. 1977. Pin oak acorn production on greentree reservoirs in southeastern Missouri. The Journal of Wildlife Management 41:218-225.

Parr, D. E., M. D. Scott, and D. D. Kennedy. 1979. Autumn movements and habitat use by wood ducks in southern Illinois. The Journal of Wildlife Management 43:102-108.

Robb, J. R., and T. A. Bookhout. 1990. Female and juvenile wood duck survival and movements in Indiana. Pages 179-184 *in* Proceedings 1988 North American wood duck Symposium, (L. H. Fredrickson, G. V. Burger, S. P. Havera, D. A. Graber, R. E. Kirby, and T. S. Taylor, editors.). St. Louis, Missouri.

Rumble, M. A., and L. D. Flake. 1982. A comparison of two waterfowl brood survey techniques. Journal of Wildlife Management 46:1048-1053.

SAS. 1989. SAS/STAT User's Guide, Version 6, Fourth Ed., Vol. 1. SAS Institute, Inc., Cary, North Carolina.

Sousa, P. J., and A. H. Farmer. 1983. Habitat suitability index models: wood duck. United States Fish and Wildlife Service FWS/OBS-82/10.43.

Swanson, G. A., M. I. Meyer, and J. R. Serie. 1974. Feeding ecology of breeding blue-winged teal. The Journal of Wildlife Management 38:396-407.

Thorp, J. H., and A. P. Covich. 1991. Ecology and classification of North American freshwater invertebrates. Academic Press, Inc., San Diego, California.

Received 10 April 1996
Accepted 1 August 1996